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STUDY OF THE IONOSPHERIC F_2-LAYER'S EVOLUTION AT LEOPOLDVILLE-BINZA

by

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SUMMARY

The current investigation of the electron density maximum of the F_2 - layer of the ionosphere shows :

1) a semi-annual g lobal variation in phase with the variation of the magnetic activity;

2) a marked semi-annual variation between 09 00 and 19 00 hours and between 23 00 and 02 00 hours UT, and a marked variation of annual periodicity for the remaining hours;

3) a considerable rate of increase with sunspot numbers between the hours of 18 00 and 24 00 local mean time.

4) a maximum between 21 00 and 23 00 hours corresponding to the half-thickness maximum.

Owing to the difficulties encountered in trying to explain these peculiarities by the only action of photoionization and drift, it seems justified to resort to the effect of extra ionization due to corpuscles accelerated in the near-the Earth region.

* * *

* ÉTUDE DE L'ÉVOLUTION DE LA COUCHE IONOSPHÈRIQUE F À LÉOPOLDVILLE-BINZA.

INTRODUCTION

The Geophysical Section of the Meteorological Service of the Belgian Congo and Ruanda-Urundi has been making ionospheric forecasts for the past several years using a new method, which has given in the whole very satisfactory results [1, 2].

The method employed is the result of a study of the evolution of the electron density maximum of the F2-layer in the vertical of Léopoldville-Binza.

Originally, we had assigned ourselves the task of establishing a comparison between the variation of this ionization maximum and the relative variation of solar radiation received on a horizontal surface outside the atmosphere. This was so much the more required that it was generally admitted that the cause of ionization was precisely an electromagnetic radiation stemming from the Sun.

A similar study had already supplied interesting results in terrestiral magnetism [3] and its further pusuit in the field of the upper atmosphere was deemed justified.

In fact, the task consisted principally to verify the relationships between the ionization and the geometry of the system Earth-Sun, whose existence could be suspected. In particular, a series of harmonic analyses should have ascertained the existence of periodicities of 12 and 6 months, as for the solar radiation, that might possibly lend themselves to easier interpretation than the diurnal variation.

We thus were led to consider separately the evolution in the course of months and years of the ionization maximum relative to each particular hour of the day despite the fact that the corresponding zenithal distance of the Sun varies considerably in the course of the seasons.

However strange it may appear at first sight, this procedure has nevertheless allowed us to elaborate a very satisfactory ionosphere forecasting method and led us to bring forth certain remarkable properties of the evolution of electron density maximum at our station. The following pages have for object to report the most striking facts made evident in in the course of this study.

GENERAL VIEW OF THE EVOLUTION OF THE ELECTRON DENSITY MAXIMUM

Let us consider first of all the evolution of the electron densirt maximum in a synthetic fashion. In order to obtain a convenient representation, let us reduce one month of observations to a "median" day, whereby the electron density would be taken equal for each hour to the median monthly figure.

An entire year may then be represented by means of 12 "median" days.

By examining the Fig. 1, which gives such a representation for the years 1952 through 1958, one may see at once the prevalence of a semi-annual wave.

Comparing the oscillation of the envelope to the well knowm semi-annual variation of the magnetic character Ap of Bartels, one is immediately struck by the morphological similitude of both phenomena.

Fig. 2 shows that this effect is universal. The minima take place in June-July and in December-January and the maxima in March-April and in September-October.

As a matter of comparison we have plotted in Figs 1 and 2 the curves for the respective variations of the solar radiation incident at noon on a unit of horizontal surface outside the atmosphere. If these curves offer a certain similitude with the data for the Southern Hemisphere, they are absolutely discordant for the Northern Hemisphere. Moreover, the solar radiation shows outside the equatorial band a marked prevalence of the annual variation over the semi-annual variation, which is not the case for the ionization.

Except for venturing the little likely hypothesis that the radiation responsible for the ionization of the F_2- layer has a strong six-month periodicity, one is forced to conclude, as regards the variation in the course of a year, that the ionization maximum of the F_2-layer does not follow the variations of solar radiation.

It is not without interest to mention here that geomagneticians consider the character of Ap as being the index of a corpuscular effect. Let us recall indeed, that the character of Ap is a measure of the degree of activity of a magnetic field; but the magnetic activity is expressed by a succession of relaxations [4] of which the most important are the magnetic

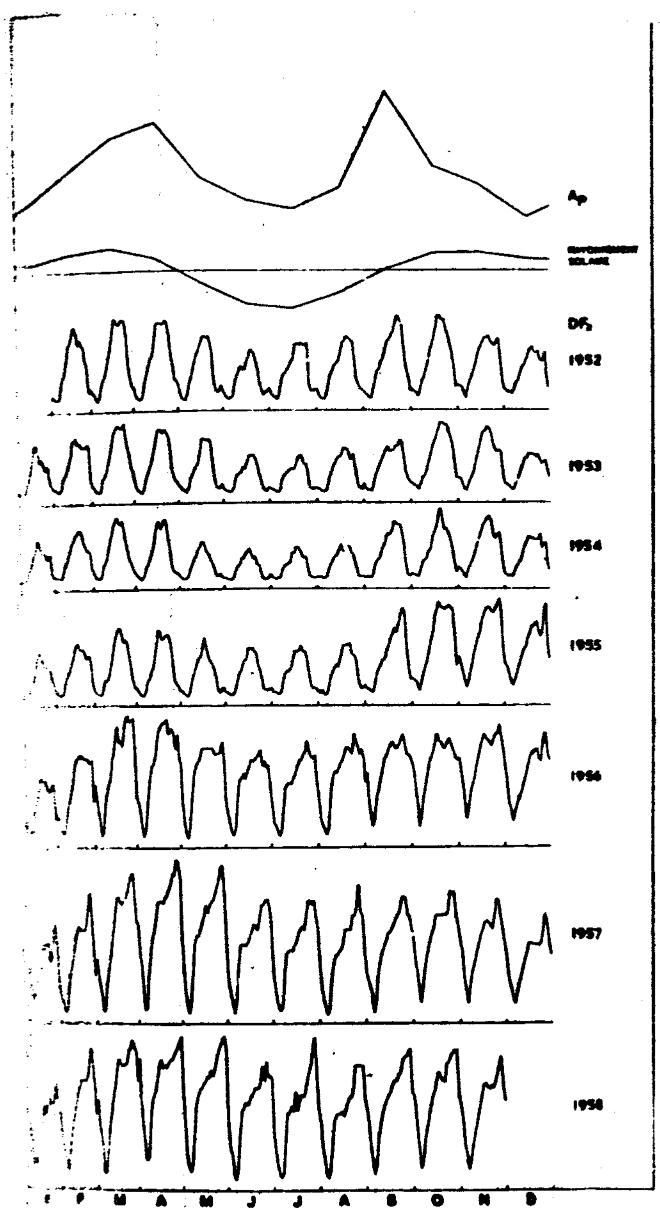
Ap
DF2
1952
1953
1954
1955
1956
1957
1958
F
M
A
M
J
J
A
S
O
N
D

Fig. 1.

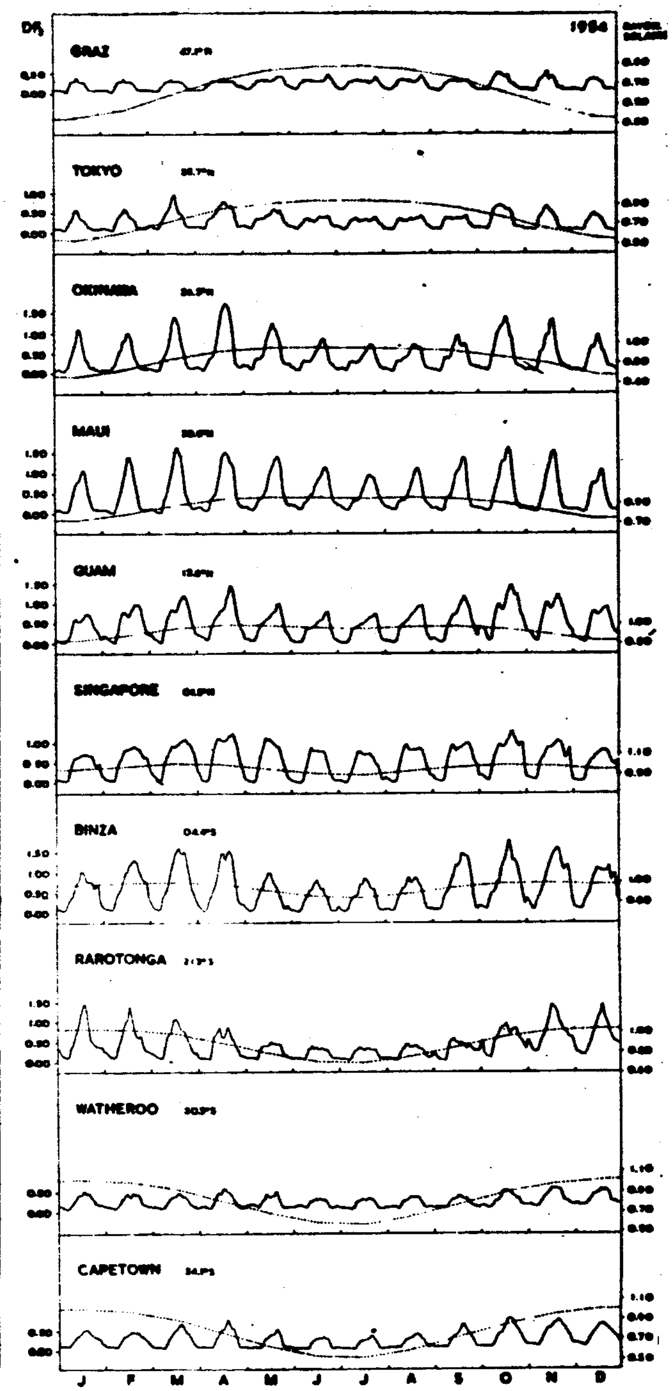
DF2
1954
GRAZ
TOKYO
OKINAWA
MAUI
GUAM
SINGAPORE
BINZA
RAROTONGA
WATHEROO
CAPETOWN
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 2.

storms. In order to explain the development of these magnetic disturbances the Chapman-Ferraro and Alfvén theories resort to the enveloping movement of a beam of particles emitted from the Sun.

On the other hand, it is well known that these magnetic disturbances are generally accompanied by ionospheric disturbances.

EVOLUTION OF ELECTRON DENSITY FOR EVERY HOUR

We have indicated in Fig. 3 the variation in time of the electron desnity maximum for certain hours taken individually after substracting the undecennial effect which is obtained by a sliding average for thirteen months.

It is striking to discover that if the predominant variation is semi-annual for certain hours, it is, to the contrary, annual for certain other ones.

This is fully corroborated by the data on the amplitudes of these waves, compiled in Table 1.

The mean amplitudes, computed for five years (1953 – 1957) show indeed that the semi-annual variation is prevalent between 0900 and 1900 hours and between 2300 and 0200 hours UT; for the other hours the annual variation is the most important.

These two waves are responsible for the existence and the position variations of the bends that can be seen on the diurnal curves of Fig. 1.

The most important conclusion to be derived from this fact is that the ionosphere must be the crossroads of two phenomena of very different essence, having a semi-annual prevalent periodicity for one of them and an annual one for the other.

EVOLUTION IN THE COURSE OF THE CURRENTLY INCREASING SOLAR ACTIVITY CYCLE

It is advantageous to make use of data clear of seasonal variations. The averaged over thirteen months values of electron density maximum do satisfy this criterion.

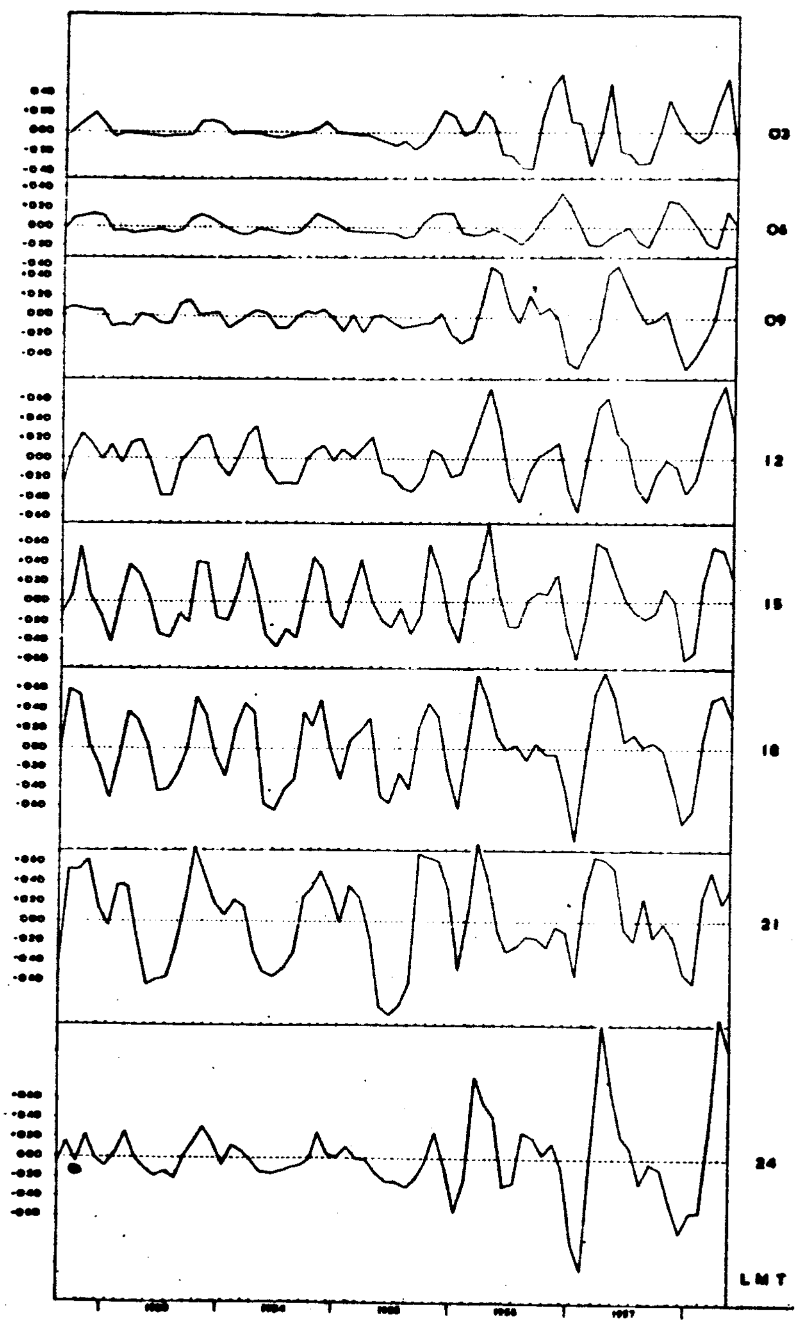

Fig. 3.

TABLEAU I

TABLE 1

AMPLITUDE DES ONDES ANNUELLES ET SEMI-ANNUELLES
DE LA DENSITÉ ÉLECTRONIQUE MAXIMUM A BINZA

HOUR HEURE	1953		1954		1955		1956		1957		MOYENNES Averages	
	C_{12}	C_6	C_{12}	C_6	C_{12}	C_6	C_{12}	C_6	C_{12}	C_6	C_{12}	C_6
00	0.07	0.09	0.05	0.05	0.07	0.10	0.14	0.51	0.25	0.44	0.12	0.24
01	0.06	0.10	0.06	0.04	0.12	0.13	0.36	0.32	0.08	0.35	0.14	0.19
02	0.06	0.04	0.05	0.02	0.12	0.08	0.30	0.25	0.09	0.28	0.12	0.13
03	0.05	0.03	0.05	0.01	0.09	0.06	0.27	0.10	0.13	0.14	0.12	0.07
04	0.03	0.00	0.03	0.01	0.07	0.02	0.18	0.03	0.09	0.05	0.08	0.02
05	0.08	0.04	0.07	0.06	0.10	0.07	0.18	0.12	0.15	0.15	0.12	0.09
06	0.04	0.03	0.04	0.07	0.02	0.06	0.10	0.14	0.20	0.12	0.08	0.08
07	0.06	0.03	0.03	0.06	0.06	0.04	0.32	0.17	0.33	0.21	0.16	0.10
08	0.08	0.05	0.02	0.08	0.03	0.07	0.29	0.27	0.37	0.20	0.16	0.13
09	0.09	0.10	0.08	0.11	0.01	0.01	0.20	0.32	0.27	0.26	0.13	0.16
10	0.13	0.14	0.16	0.13	0.09	0.18	0.14	0.42	0.24	0.29	0.15	0.23
11	0.13	0.24	0.18	0.16	0.14	0.17	0.22	0.43	0.35	0.59	0.20	0.32
12	0.22	0.29	0.17	0.24	0.16	0.25	0.25	0.46	0.33	0.42	0.23	0.33
13	0.19	0.28	0.19	0.25	0.15	0.30	0.20	0.48	0.31	0.40	0.21	0.34
14	0.15	0.30	0.22	0.33	0.11	0.28	0.15	0.39	0.28	0.36	0.18	0.33
15	0.11	0.34	0.26	0.43	0.15	0.33	0.19	0.33	0.30	0.36	0.20	0.36
16	0.11	0.38	0.28	0.42	0.21	0.34	0.23	0.27	0.33	0.41	0.23	0.36
17	0.16	0.38	0.30	0.40	0.18	0.41	0.31	0.37	0.49	0.37	0.29	0.39
18	0.23	0.40	0.30	0.31	0.23	0.55	0.37	0.46	0.59	0.37	0.34	0.42
19	0.32	0.39	0.32	0.29	0.38	0.61	0.17	0.56	0.39	0.43	0.32	0.46
20	0.51	0.30	0.46	0.17	0.64	0.48	0.27	0.29	0.39	0.36	0.45	0.32
21	0.60	0.18	0.50	0.12	0.75	0.32	0.31	0.23	0.60	0.50	0.55	0.27
22	0.43	0.16	0.33	0.07	0.35	0.31	0.45	0.38	0.79	0.54	0.47	0.20
23	0.16	0.12	0.13	0.03	0.08	0.16	0.20	0.47	0.64	0.49	0.24	0.25

Table 1. - Amplitude of Annual and Semi-annual Waves of Electron Density Maximum at Binza.

Fig. 4 (next page) gives a representation of the electron density maximum for all the hours of the day as a function of the number of sunspots, also averaged over 13 months.

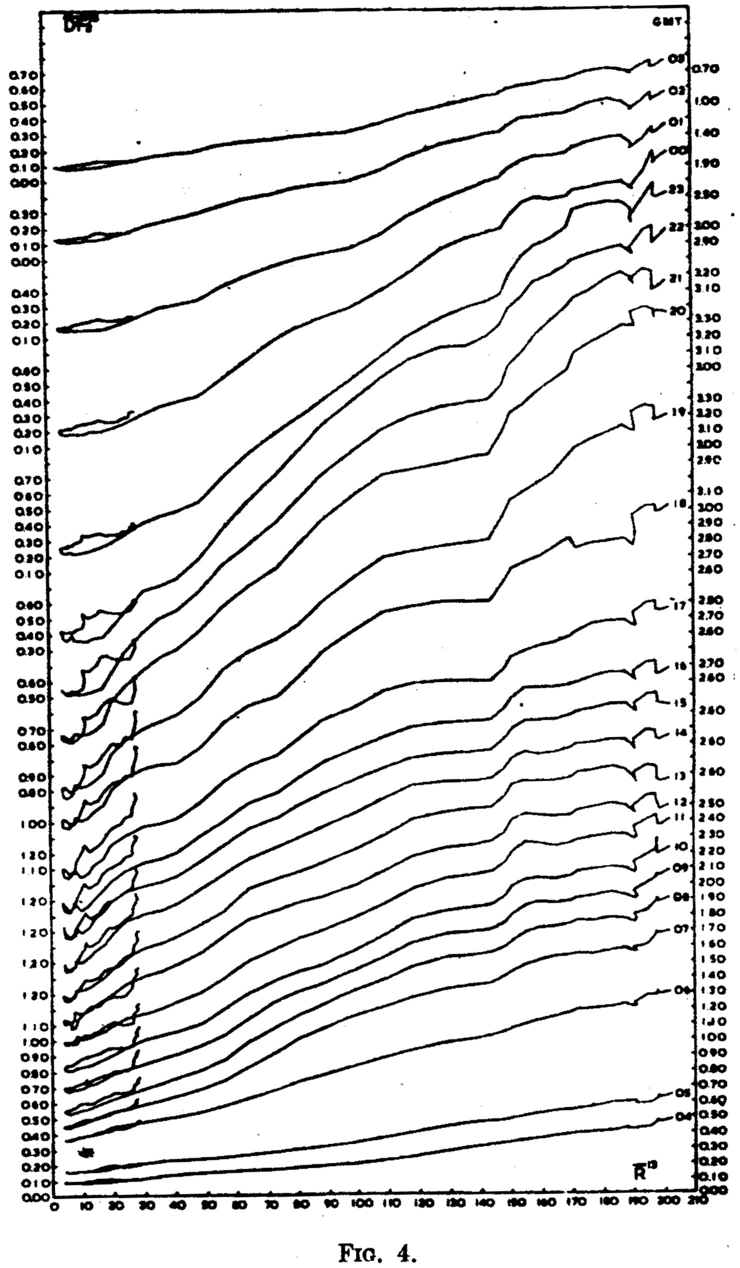

Fig. 4.

First of all the existence is noted of a saturation phenomenon particularly evident for the hours of lighting. Because the level of the solar activity maximum reached is different for every hour, one may conclude that the cause of saturation does not have its seat in the ionosphere, but in the very phenomenon responsible for the ionization.

During the night, to the contrary, between 21 00 and 06 00 hours the linearity is very satisfactory and the Wolf-Wolfer number proves to be a precious index for the representation of solar activity in the upper atmosphere.

During the illumination period and at the beginning of the evening, more particularly around 18 00 hours local time, when the shift relative to a linear relation is strongest, a screen effect seems to be in the making.

It is also remarkable that the noted accretion rate of ionization maximum varies considerably in the course of the day, as thus is shown in Table II hereafter.

TABLE II

VALUE OF THE ACCRETION RATE IN MILLIONS OF ELECTRONS PER CM^3 OF THE IONIZATION MAXIMUM BETWEEN 150 AND 200 SUNSPOTS

HOURS LMT	RATE FOR 50 SPOTS	HOURS LMT	RATE FOR 50 SPOTS
—	—	—	—
00	0.40	12	0.09
01	0.27	13	0.04
02	0.20	14	0.14
03	0.17	15	0.16
04	0.14	16	0.18
05	0.14	17	0.31
06	0.22	18	0.40
07	0.26	19	0.54
08	0.27	20	0.67
09	0.27	21	0.53
10	0.23	22	0.48
11	0.19	23	0.53

This phenomenon of ionization maximum accretion is still more evident on Figs 5 and 6, where we plotted in abscissa the hours and in ordinates the respective ratios and differences between the ionization maximum for 50, 100, 150 and 200 susspots.

As a matter for comparison, the ratios of electron density maximum, extrapolated for zero zenithal distance of the Sun for the E-layer, are respectively : 1,13 for 50 sunspots, 1,28 for 100, 1,44 for 150 and 1,54 for 200 sunspots.

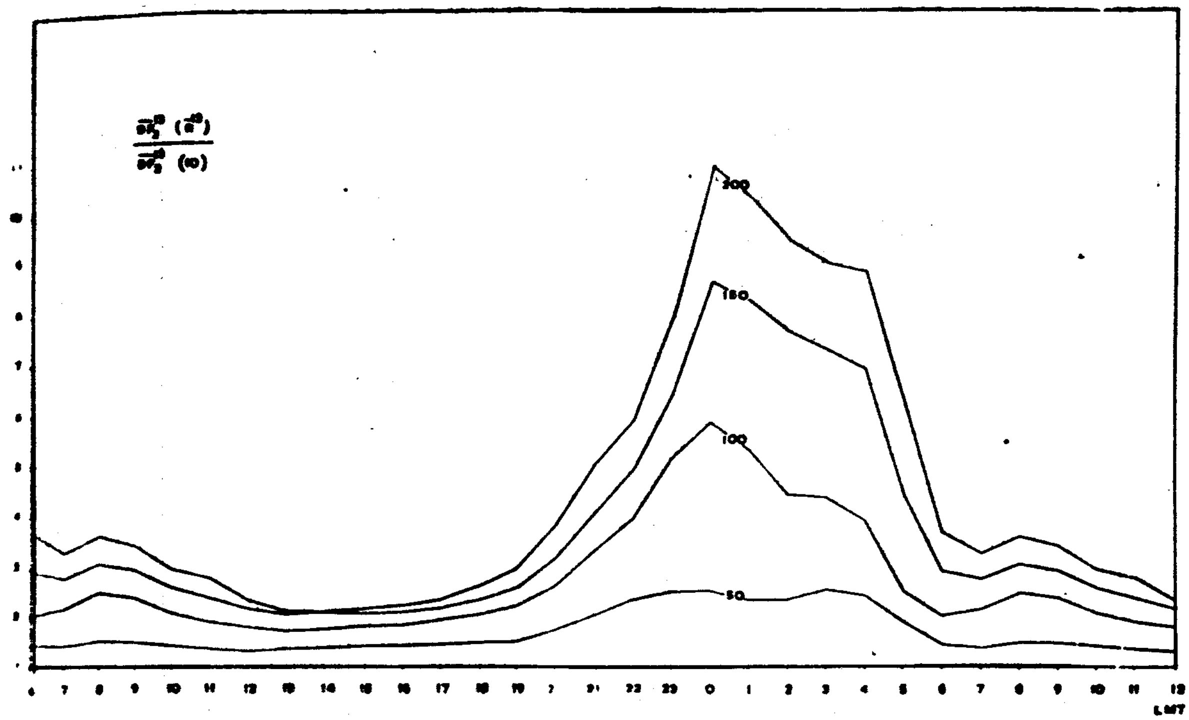

FIG. 5.

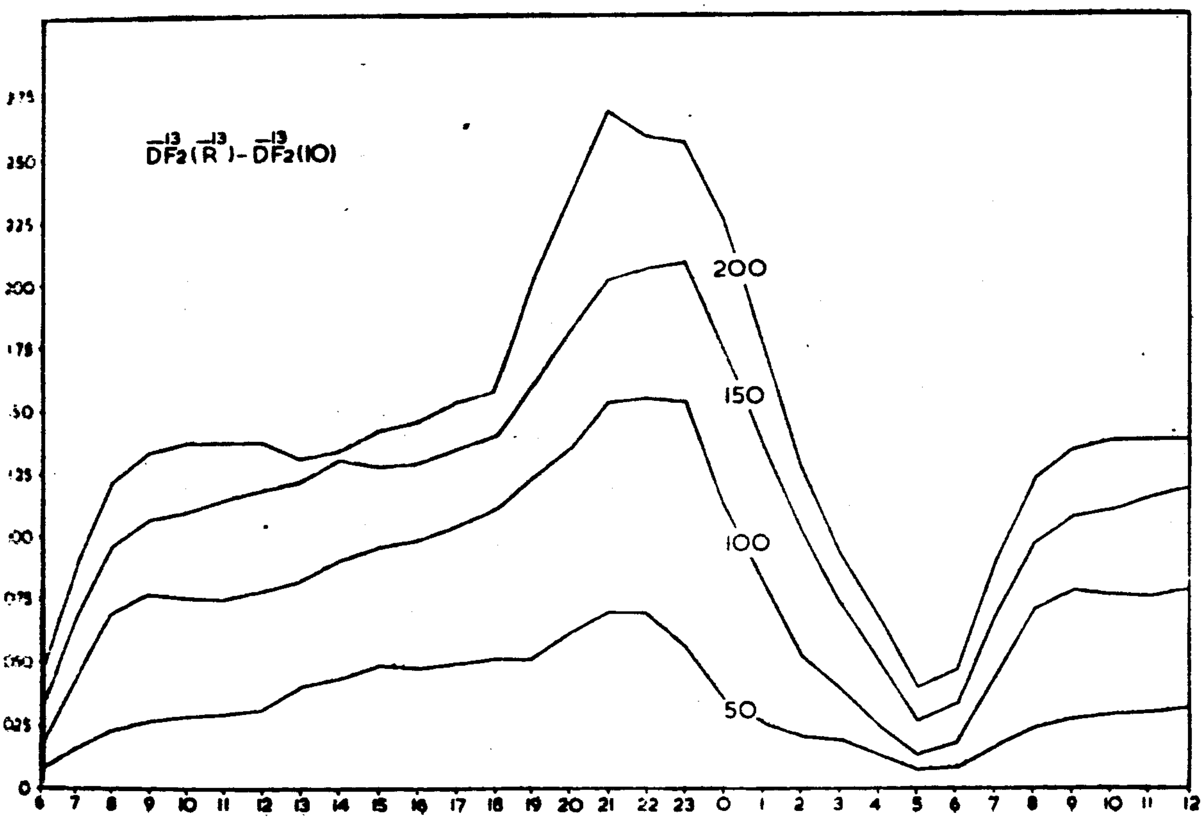
$\overline{DF2}^{13}(\overline{R}^{13})-\overline{DF2}^{13}(10)$
200
150
100
50

FIG. 6.

Thus, the ratios and the differences are much lesser for this layer.

The ionization accretion shows a considerable maximum between 21 00 and 23 00 hours LT, that is, 3 to 4 hours after sunset. The maximum of the ratio $DF_2(R)/DF_2(10)$ spreads still later into the night and in a somewhat decreasing fashion from 03 00 to 04 00 hoirs. At 200 sunspots the ionization maximum is nearly 11 times higher than in the period of minimum activity and more twice that of the secondary maximum taking place at 10 00 hours.

Finally, starting from 23 00 hours the ionization maximum decreases in 6 hours by about one tenth of its value.

CONCLUSIONS

Summarizing, we may state that the ionization maximum of the F_2-layer at the Léopoldville-Binza vertical offers the following peculiarities :

1) a global variation clearly of semi-annual period in phase with the variation of magnetic activity, corpuscular effect;

2) a prevalent semi-annual variation between 09 00 and 19 00 hrs and 23 00 and 02 00 hours UT and a preponderant annual variation for the other hours;

3) a maximum situated between 21 00 and 23 00 hours;

4) a considerable accretion rate between 18 00 and 24 00 hours LMT as a function of the number of sunspots ;

5) a saturation effect between 07 00 and 19 00 hours UT, whereas for the other hours there exists a linearity, almost perfect vs the number of sunspots.

Prior to concluding it should still be noted that the semi-thickness **ym** given by

$$ym = hp - h'$$

shows a minimum near noontime and an accentuated maximum between 18 00 and 23 00 hours.

It results therefrom that the considerable ionization density of the first part of the night can not be ascribed to a compression effect of the F_2-layer.

That part of the ionized gas would have been carried in the equatorial zone of the illuminated hemisphere toward the dark one, this has been demonstrated by Martyn [5]. It is doubtful, however, that the enormous ionization noted between 2100 and 2300 hours, is due entirely to this effect.

It is still more difficult to admit that this mechanism may explain the considerable accretion rate of ionization during the first part of the night with the number of sunspots.

The existence of a marked six-month periodicity and its similitude with the magnetic activity compels us to resort somewow to the corpuscular flux in order to explain the major part of the night ionization.

The hypothesis that is required is thus to ascribe the ionization of the F_2-layer to a double cause, photonic and corpuscular.

The fact that no one had yet been successful in clearly ascertain an eclipse effect for that layer is a corroboration of this viewpoint.

Assuming the corpsucular flux as being emitted from the Sun leads us to difficulties. It should indeed follow a law similar to that of cosmic ray decrease as a function of the latitude. However, the ionization of F_2 is much more important between the tropics than in the higher latitude regions.

Moreover, high-energy corpuscles being carried by a flux of limited importance, lack the capacity of producing a sufficient ionization.

The difficulties are partly resolved if we assume that the particles originate from regions much nearer to Earth, for example, from that region of high particle density ascertained by the AES and possibly even from the ring current, to which one resorts to explain the magnetic storms, on the condition to attribute it a sufficient perenniality.

These particles would be endowed with a relatively low energy and they might penetrate into the upper atmosphere on account of a peculiarity in the geomagnetic field or of existence of an electric field. They would yield all their energy in the form of ionization.

The theoretical difficulties implied by an ionization mode of corpuscular type are particularly arduous due to our ignorance of certain important physical parameters of the uppermost atmosphere, in particular those relative to the existence of electric fields due to space charges. If our interpretation is correct, the problem of ionization of the F2-layer would thus be linked to that of the explanation of magnetic disturbances, polar aurorae and cosmic ray variations.

We wish to thank M. Goris for having accepted to take charge of calculations and we express all our gratitude to M. Vander Elst for his interest and encouragement he never ceased to provide us with in the course of this study.

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**** THE END ****

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REFERENCES

[1].- P. HERRINCK.- Analyse de la variation annuelle et siemi-annuelles de la fréquence dritique de la couche F_2 a Léopoldville-Binza Miscelanea Geofisica.- Publicada pelo Servicò Meteorologico. Luanda 1956

[2].- P. HERRINCK.- Méthode nouvelle de prédiction.-Premiers résultats. Public.du Serv.Meteorolog. du Congo Belge et Ruanda-Urundi 1956.

[3].- P. HERRINCK.- La variation annuelle et semi-annuelle du champ magnétique horizontal et le rayonnement solaire. Bull.Academ.Roy. des Sc.coloniales. N.S.III, 6, 1200, 1957

[4].- P. HERRINCK.- Sur les perturbations du champ magnétique terrestre considérées comme variations de relaxation. Ann.de Géoph. 13, 211, 1957.

[5].- D. F. MARTYN.- Physics of the Ionosphere., p.260, London Physical Soc.

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